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(54) **METHOD FOR REPAIRING A PITCH SYSTEM IN A WIND TURBINE**

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H02K 15/00 (2006.01)
H02K 15/14 (2006.01)
H02K 15/16 (2006.01)
F03D 1/00 (2006.01)
F03D 7/02 (2006.01)

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CPC **F03D 1/003** (2013.01); **F03D 7/0224**
(2013.01); **F05B 2230/60** (2013.01); **F05B**
2260/79 (2013.01)

(58) **Field of Classification Search**
CPC B66C 1/108; B66C 13/085; F01D 25/28;
F03D 1/003; F03D 1/0658; F03D 7/0224;
F03D 11/00; F03D 11/02; F03D 11/0008;
F05B 2260/79; F05B 2260/98; F05B 2230/60;

F16C 41/02; F16C 19/38; F16C 23/08;
F16C 27/04; F16C 33/3818; F16C 33/60;
Y10T 29/37; Y10T 29/49009; Y10T 29/4973;
Y10T 49/7187
USPC 29/402.01, 402.08, 592.1, 592, 596,
29/598, 889.1; 416/47, 104, 131, 155, 174
See application file for complete search history.

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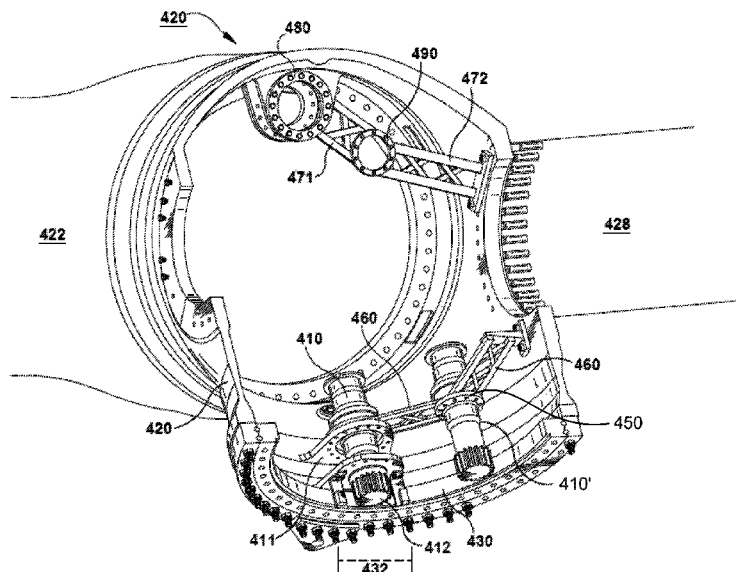
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(57) **ABSTRACT**

A replacement motor mount for a pitch system of a wind turbine includes a bracket assembly configured for attachment to a first motor mount and a second supporting structure. The replacement motor mount is configured for mounting and securing a pitch motor having a geared drive end. The replacement motor mount is configured to displace the pitch motor from the first motor mount by a predetermined distance.

12 Claims, 5 Drawing Sheets



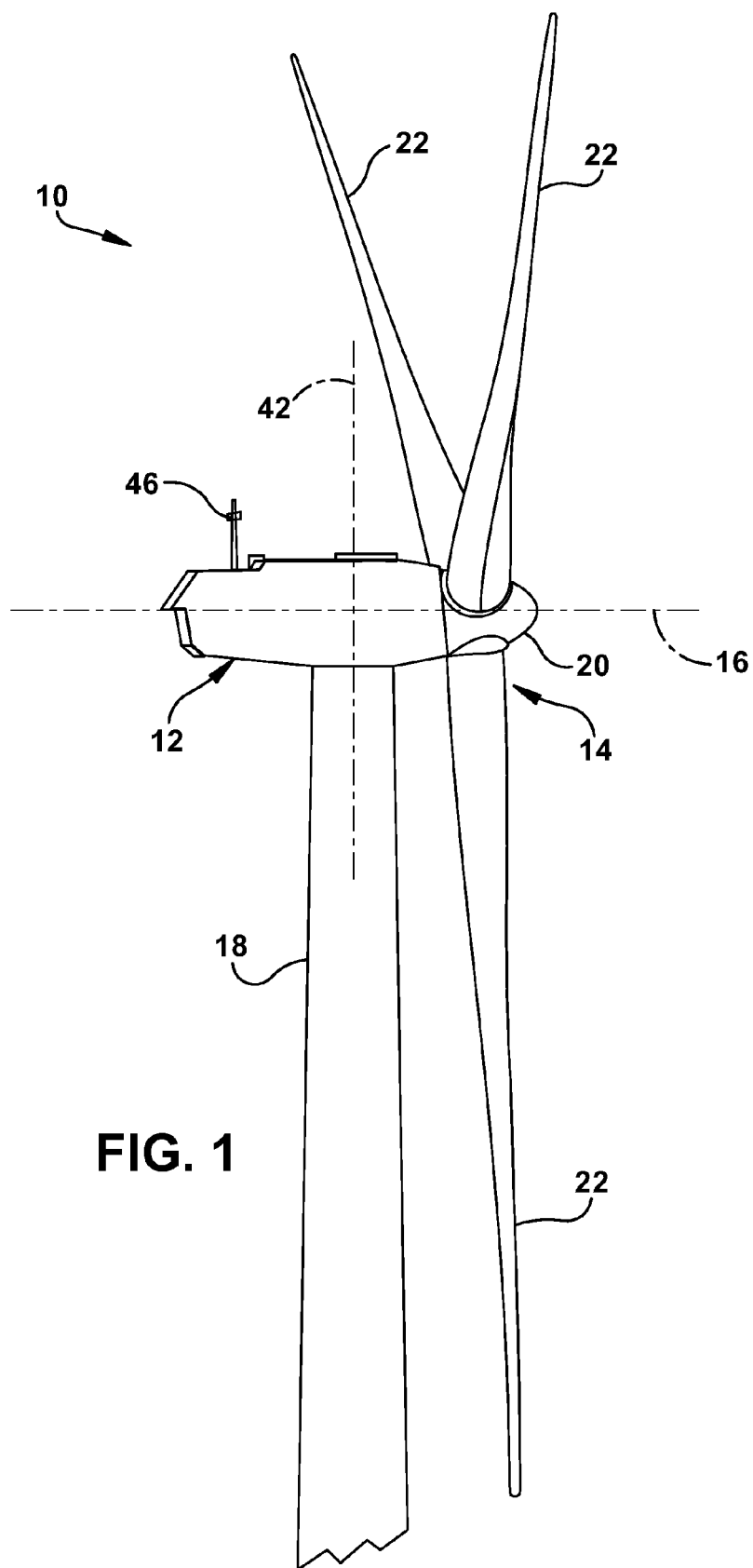
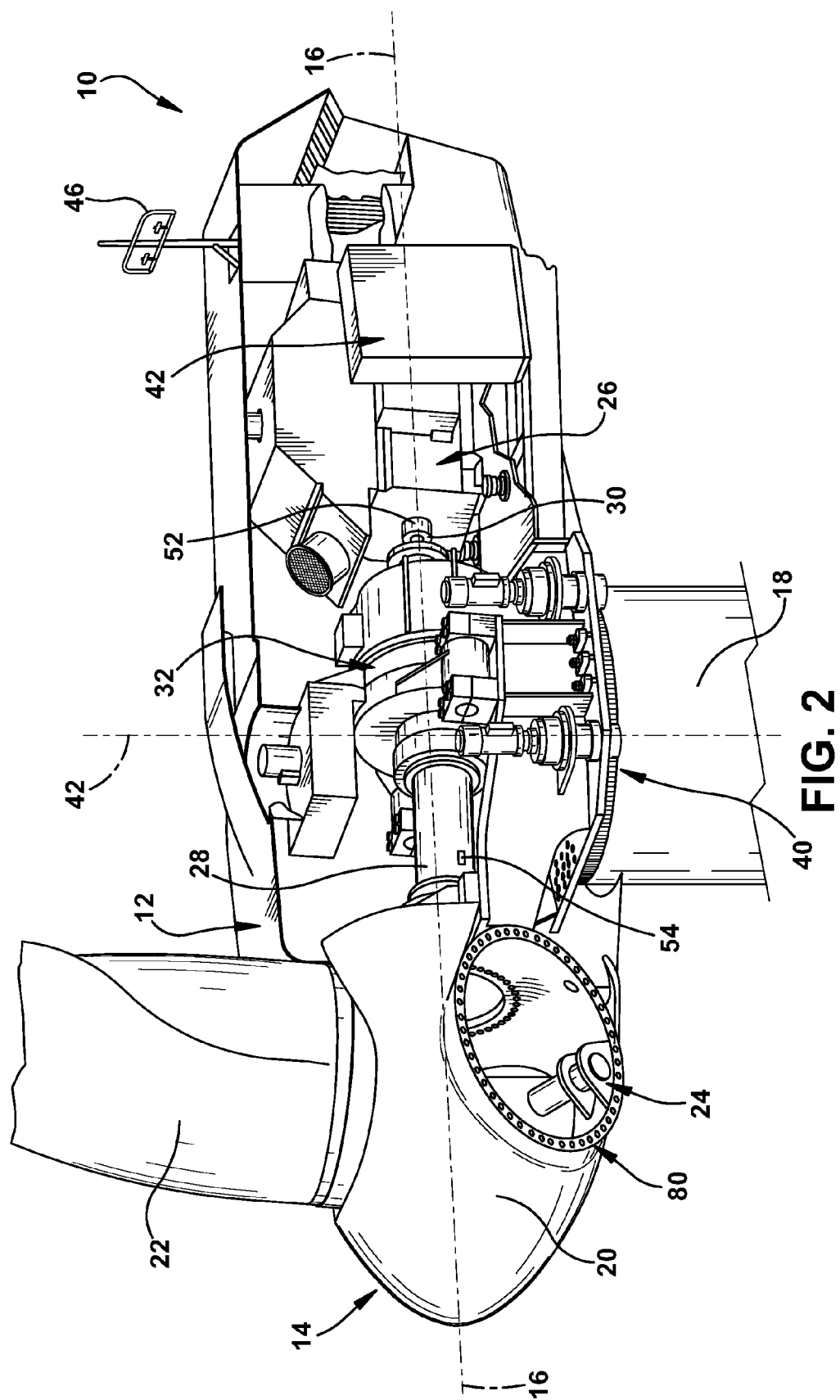
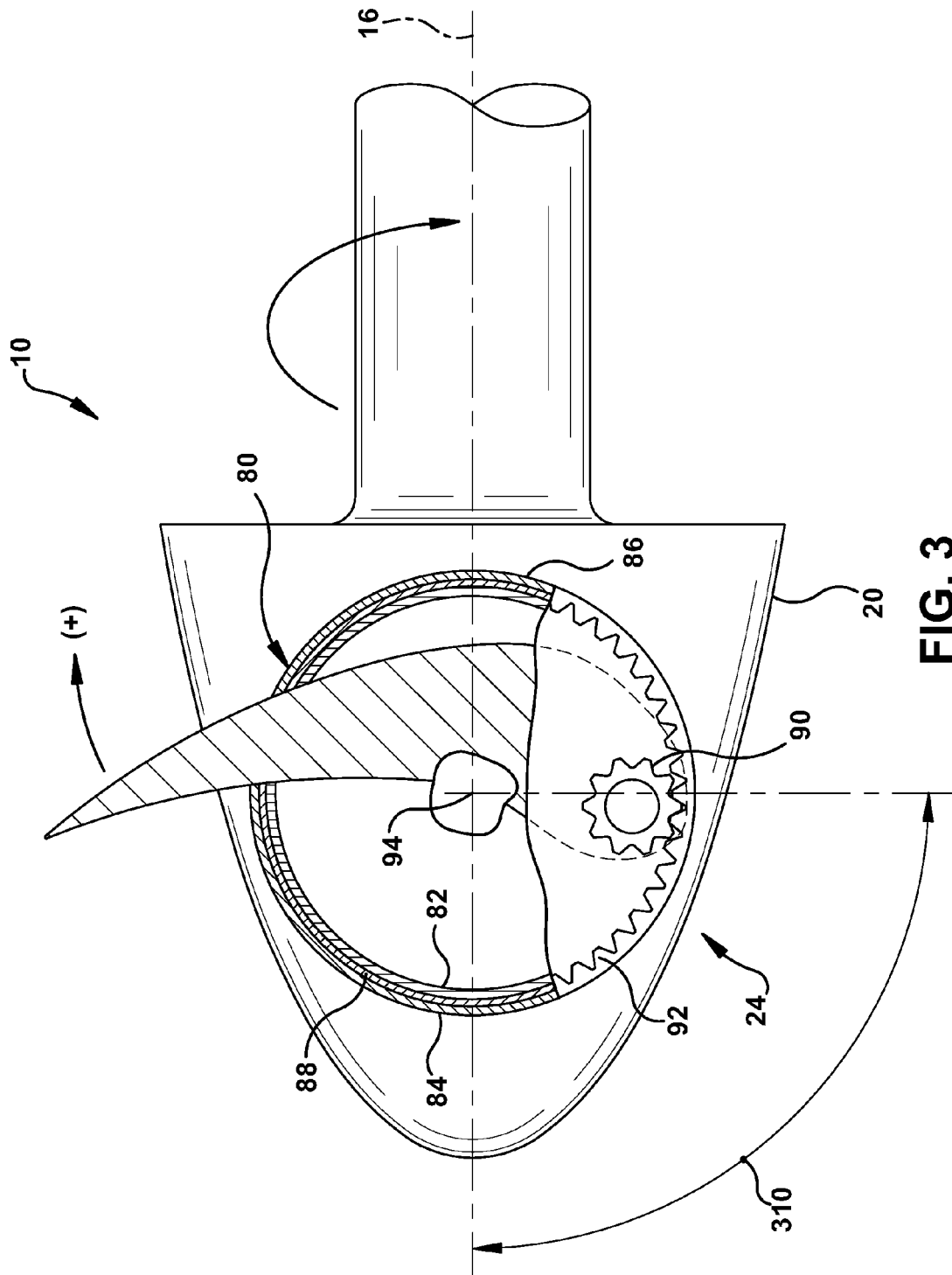
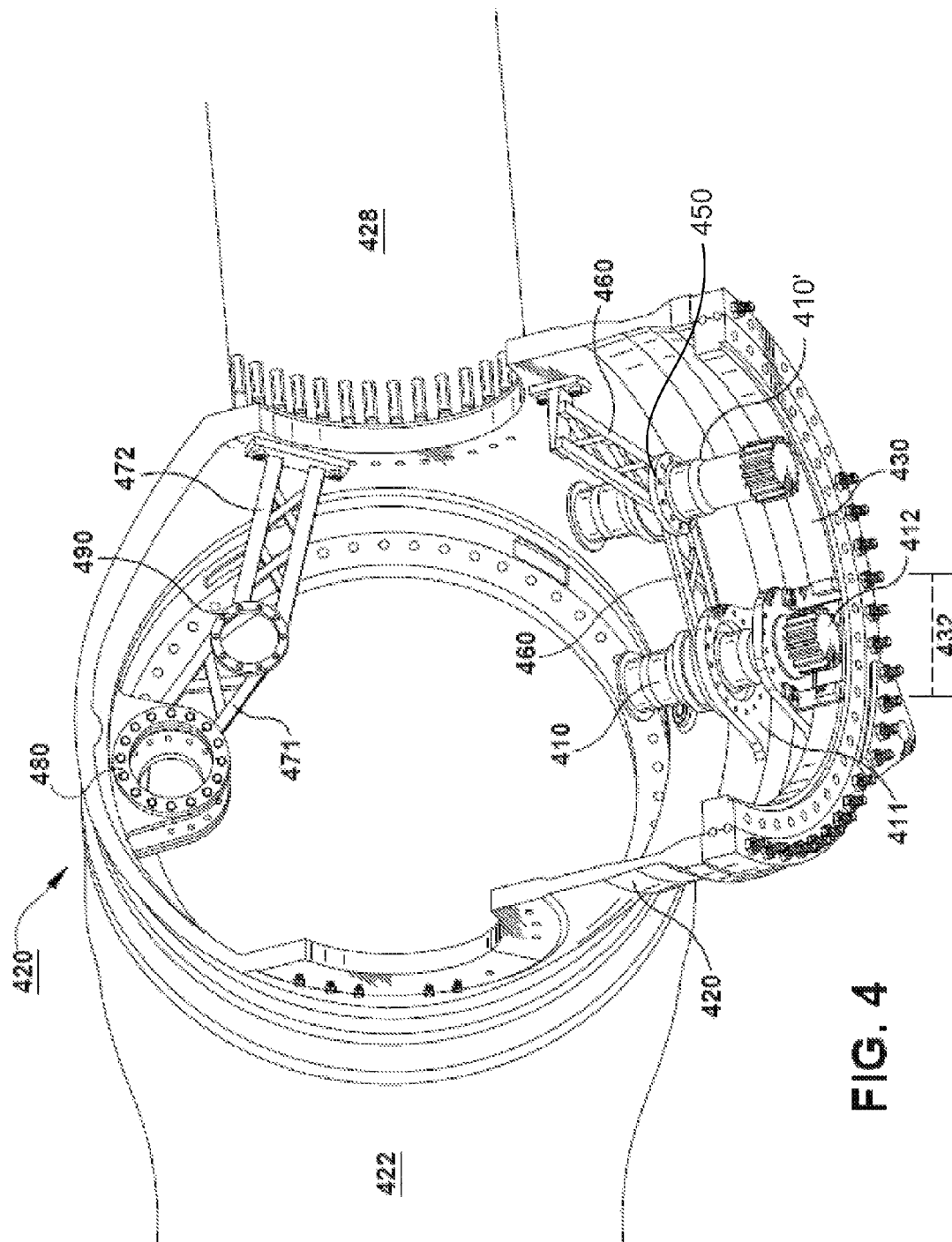


FIG. 1







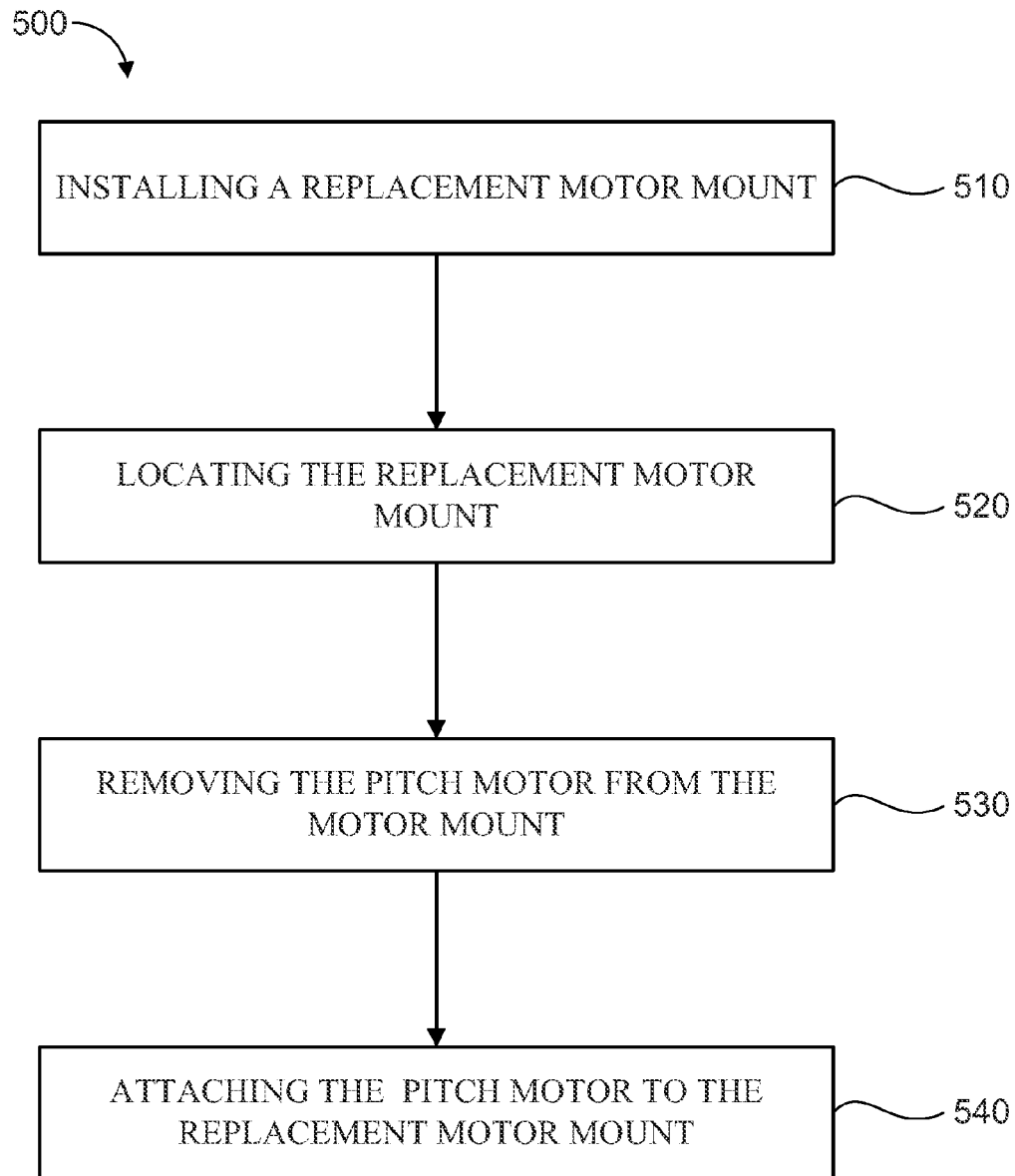


FIG. 5

METHOD FOR REPAIRING A PITCH SYSTEM IN A WIND TURBINE

BACKGROUND OF THE INVENTION

This invention relates generally to wind turbines, and more specifically to a replacement motor mount for a pitch system and a method for installing the replacement motor mount.

Some known wind turbines have pitch control systems comprised of a bearing coupled between a blade and a hub with a pitch motor positioning the blade attached to the bearing. The bearing may include a row of teeth that engage a gear of the motor. The motor's gear turns or pitches the blade by interacting with the teeth on the pitch bearing. Over time some of the bearing's teeth can become damaged, worn or may break off. The portion of the ring gear adjacent to the pitch motor is one region that often experiences excessive wearing. Current known solutions to repair a pitch control component require the removal of the affected blade or the entire rotor. In either case, a large crane is required for removal, and cranes of this type are costly. In addition, the wind turbine is taken off-line until the repairs can be completed.

In some wind turbines, the blades are up to 60 meters in length, but may be designed to be up to 100 meters, so removal to change a damaged pitch control system can be costly and time consuming. Other known wind turbines are offshore, requiring extensive equipment to remove a blade and replace the pitch control system components. Wind turbine hub heights can be over 120 meters and in high winds, making it dangerous for workers to be on the wind turbine.

A malfunctioning pitch control system can also cause a blade to move out of a pitch setting such that the blades of the wind turbine asymmetrically load the hub and rotor shaft. If the rotor begins to move within the stator due to the asymmetric loading, there is a possibility of the rotor contacting the stator, for example, in direct drive application with the turbine rotor being attached directly to the generator. An electrical transient can occur if the rotor and stator contact, and the wind turbine may then have to be taken off-line.

BRIEF DESCRIPTION OF THE INVENTION

In one aspect of the present invention, a replacement motor mount for a pitch system of a wind turbine includes a bracket assembly configured for attachment to a first motor mount and a second supporting structure. The replacement motor mount is configured for mounting and securing a pitch motor having a geared drive end. The replacement motor mount is configured to displace the pitch motor from the first motor mount by a predetermined distance.

In another aspect of the present invention, a motor mount for a pitch system of a wind turbine includes a first motor mount configured to secure a pitch motor, and a replacement motor mount configured as an alternate location for the pitch motor. The replacement motor mount is configured to displace the pitch motor from a location of the first motor mount by a predetermined distance; and wherein the predetermined distance is chosen to avoid interaction between a geared drive end of the pitch motor and a damaged region of a pitch bearing.

In still another aspect of the present invention, a method for repairing a pitch system in a wind turbine is provided. The pitch system includes a pitch bearing, a pitch motor and a motor mount for the pitch motor. The method includes the steps of, installing a replacement motor mount for the pitch motor, locating the replacement motor mount to displace the

pitch motor from the motor mount by a predetermined distance, and attaching the pitch motor to the replacement motor mount. The predetermined distance is chosen to reduce interaction between a geared drive end of the pitch motor and a damaged region of the pitch bearing.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective illustration of an exemplary wind turbine;

FIG. 2 is a partially cut-away perspective illustration of a portion of the wind turbine shown in FIG. 1;

FIG. 3 is a cross-sectional view illustration of a portion of a rotor hub of the wind turbine shown in FIGS. 1-2 illustrating an exemplary embodiment of a pitch system;

FIG. 4 illustrates a partial perspective view of a replacement motor mount, according to an aspect of the present invention; and

FIG. 5 illustrates a flow chart of a method for repairing a pitch system in a wind turbine, according to an aspect of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

As used herein, the term "blade" is intended to be representative of any device that provides reactive force when in motion relative to a surrounding fluid. As used herein, the term "wind turbine" is intended to be representative of any device that generates rotational energy from wind energy, and more specifically, converts kinetic energy of the wind into mechanical energy. As used herein, the term "wind generator" is intended to be representative of any wind turbine that generates electrical power from rotational energy generated from wind energy, and more specifically, converts mechanical energy converted from kinetic energy of wind to electrical power. As used herein, the term "windmill" is intended to be representative of any wind turbine that uses rotational energy generated from wind energy, and more specifically mechanical energy converted from kinetic energy of wind, for a predetermined purpose other than generating electrical power, such as, but not limited to, pumping a fluid and/or grinding a substance.

FIG. 1 is a perspective view of an exemplary embodiment of an exemplary wind turbine 10. Wind turbine 10 described and illustrated herein is a wind generator for generating electrical power from wind energy. In some known wind turbines, wind turbine 10 is any type of wind turbine, such as, but not limited to, a windmill (not shown). Moreover, wind turbine 10 described and illustrated herein includes a horizontal-axis configuration. In some known wind turbines, wind turbine 10 includes a vertical-axis configuration (not shown). Wind turbine 10 may be coupled to an electrical load (not shown), such as, but not limited to, a power grid (not shown), and may receive electrical power therefrom to drive operation of wind turbine 10 and/or its associated components and/or may supply electrical power generated by wind turbine 10. Although only one wind turbine 10 is shown in FIGS. 1-3, in some embodiments a plurality of wind turbines 10 are grouped together, to form a "wind farm".

Wind turbine 10 includes a nacelle 12, and a rotor (generally designated by 14) coupled to body 12 for rotation with respect to body 12 about an axis of rotation 16. In the exemplary embodiment, nacelle 12 is mounted on a tower 18. The height of tower 18 is any suitable height enabling wind turbine 10 to function as described herein. Rotor 14 includes a hub 20 and a plurality of blades 22 (sometimes referred to as "airfoils") extending radially outwardly from hub 20 for con-

verting wind energy into rotational energy. Although rotor **14** is described and illustrated herein as having three blades **22**, rotor **14** may include any number of blades **22**.

FIG. 2 is a partially cut-away perspective view of a portion of the exemplary wind turbine **10**. Wind turbine **10** includes an electrical generator **26** coupled to rotor **14** for generating electrical power from the rotational energy generated by rotor **14**. Generator **26** is any suitable type of electrical generator, such as, but not limited to, a wound rotor induction or permanent magnet generator. Rotor **14** includes a low speed rotor shaft **28** coupled to rotor hub **20** for rotation therewith. Generator **26** is coupled to a high speed rotor shaft **30** such that rotation of rotor shaft **28** drives rotation of the generator rotor, and therefore operation of generator **26**. In the exemplary embodiment, high speed rotor shaft **30** is coupled to low speed shaft **28** through a gearbox **32**, although in other embodiments generator rotor shaft **30** is coupled directly to rotor shaft **28**. The rotation of rotor **14** drives the generator rotor to thereby generate variable frequency AC electrical power from rotation of rotor **14**.

In some embodiments, wind turbine **10** includes a brake system (not shown) for braking rotation of rotor **14**. Furthermore, in some embodiments, wind turbine **10** includes a yaw system **40** for rotating nacelle **12** about an axis of rotation **42** to change a yaw of rotor **14**. Yaw system **40** is coupled to and controlled by a control system(s) **44**. In some embodiments, wind turbine **10** includes anemometry **46** for measuring wind speed and/or wind direction. Anemometry **46** is coupled to control system(s) **44** for sending measurements to control system(s) **44** for processing thereof. In the exemplary embodiment, control system(s) **44** is mounted within nacelle **12**. Alternatively, one or more control systems **44** may be remote from nacelle **12** and/or other components of wind turbine **10**. Control system(s) **44** may be used for, but is not limited to, overall system monitoring and control including, for example, pitch and speed regulation, high-speed shaft and yaw brake application, yaw and pump motor application, and/or fault monitoring. Alternative distributed or centralized control architectures may be used in some embodiments.

FIG. 3 is a cross-sectional view of a portion of hub **20** illustrating an exemplary embodiment of a pitch system **24**. Wind turbine **10** includes variable blade pitch system **24** for controlling a pitch angle of rotor blades **22** with respect to a wind direction. Pitch system **24** is coupled to control system(s) **44** for control thereby. Blade **22** and pitch system **24** are coupled to pitch bearing **80** housed in hub **20**. Pitch bearing **80** has an inner race **82** and a concentric outer race **84**. Inner race **82** is coupled to blade **22** and outer race **84** is coupled to pitch system **24**. An annular groove **86** is defined between inner race **82** and outer race **84** and includes at least one material **88** which reduces friction when inner race **82** and outer race **84** move with respect to each other. Material **88** is at least one of rollers or balls (not shown) or a lubricant or low-friction material (not shown). Alternatively, blade **22** is coupled to outer race **84**, and inner race **82** is coupled to hub **20** wherein pitch system **24** drives outer race **84** to control the position of blade **22**.

In some embodiments, pitch system **24** includes one or more actuators. The pitch actuators include any suitable structure, configuration, arrangement, means, and/or components, such as, but not limited to, electrical motors, hydraulic cylinders, springs, and/or servomechanisms. Moreover, the pitch actuators are driven by any suitable means, such as, but not limited to, hydraulic fluid, electrical power, electrochemical power, and/or mechanical power, such as, but not limited to, spring force. In some embodiments, the pitch actuators are driven by energy extracted from at least one of a

rotational inertia of rotor **14** and a stored energy source (not shown) that supplies energy to components of wind turbine **10**. In the exemplary embodiment, pitch system **24** includes a pitch drive gear **90** and a toothed pitch ring gear **92** coupled to hub **20** and blades **22** via bearing **80**. Pitch system **24** utilizes actuators for changing the pitch angle of blades **22** by rotating blades **22** coupled to inner race **82** with respect to hub **20** and outer race **84**. More specifically, in the exemplary embodiment, the pitch actuators include a pitch drive gear **90** that is coupled to a pitch ring gear **92**. Pitch ring gear **92** is coupled to blade **22** such that rotation of pitch drive gear **90** rotates blade **22** about an axis of rotation **94** to thereby change the pitch of blade **22**.

As described earlier, the teeth of pitch ring gear **92** can become damaged or worn, no longer providing the correct functionality. Known repairs for this issue involve replacing or turning the pitch bearing to engage the pitch drive pinion with undamaged gear teeth. To change the bearing, the blade and or rotor must be removed, resulting in a difficult and costly operation involving high capacity cranes with high reaches.

The method and system, according to aspects of the present invention, include providing a pitch drive mount that can be brought up into the hub and attached to the hub either using self-fixturing or separate tooling to drill and tap mounting holes in the hub, thus enabling a pitch drive to be applied to an undamaged section of the pitch ring gear teeth. Typically, only about one quadrant **310** of the pitch ring gear teeth are actually driven by the pitch drive gear **90**, and often the damage is restricted to less than that, sometimes only one to a few teeth. The method of the present invention enables several repairs over the life of the turbine without having to drop the rotor or reposition the bearing.

FIG. 4 illustrates a partial perspective view of a replacement motor mount, according to an aspect of the present invention. The hub **420** is connected to the low speed shaft **428**. The pitch motor **410** is mounted to a motor mount **411**. Motor mount **411** may also be referred to as a first motor mount. The pitch motor **410** includes a geared drive end **412** that interacts with a geared portion of a pitch bearing gear **430**. The pitch motor **410** may also be referred to as the pitch motor/drive assembly. As mentioned previously, one quadrant of the pitch bearing is driven by the pitch motor, and this quadrant can become excessively worn. Typically this wear is localized to a small region **432** of the pitch bearing, so if this region could be avoided then the wind turbine can continue to be used without requiring a total blade **422** or rotor removal.

When excessive wear occurs, a replacement motor mount **450** (or **490**) may be installed a predetermined distance away from the previous motor mount **411**. The replacement motor mount **450**, **490** may also be referred to as a second motor mount. The predetermined distance is chosen to avoid or reduce interaction with the damaged region **432** of the pitch bearing gear **430**. For example, the replacement motor mount **450** location could be spaced from the previous motor mount **411** by about 10 to about 25 degrees or more. This would effectively avoid the damaged region **432** during the starting and stopping phase of the pitch cycle, which is when the gear **430** experiences the most load from the drive end **412** of the pitch motor **410**.

The motor mount **450** includes, or may be attached to, a bracket assembly **460** configured for mounting and securing the pitch motor **410** (or a replacement motor). The bracket assembly **460** is configured for attachment to a previous (or first) motor mount **411** and a second supporting structure (which could be a portion of the hub **420**). The brackets, **460**, **471** and **472** are configured to support and stabilize the

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respective replacement motor mounts **450, 490**. For example, the bracket assembly **471, 472** may include a first bracket member **471** connected to the previous (or first) motor mount **480** and the replacement motor mount **490**, and a second bracket member **472** connected to the motor mount **490** and the hub **420**. The hub connection could be any suitable location, such as preexisting holes or new holes could be drilled for any required fasteners. The existing pitch motor **410** may be moved to the replacement motor mount **450**, and the pitch motor mounted in replacement motor mount **450** is indicated by **410'**.

FIG. 5 illustrates a flow chart of a method **500** for repairing a pitch system in a wind turbine. As described previously, the pitch system **24** includes a pitch bearing **80**, a pitch motor **410** and a motor mount **411** for the pitch motor. The method includes a step **510** of installing a replacement motor mount **450** for the pitch motor **410**. Step **520** locates the replacement motor mount **450** to displace the pitch motor **410** (**410'**) from the motor mount **411** by a predetermined distance. The predetermined distance is chosen to reduce interaction between a geared drive end **412** of the pitch motor **410, 410'** and a damaged region **432** of the pitch bearing. As one example only, the predetermined distance spaces the replacement motor mount **450** about 10 degrees to about 25 degrees or more away from the motor mount **411** (and damaged region **432**). An optional step **530**, removes the pitch motor **410** from the original motor mount **411**. This step may be performed before the subsequent attaching step **540**. The old motor **410** may be reused in the new location (**410'**), or a new pitch motor may be installed in the new location of replacement mount **450**. In step **540**, the pitch motor **410'** is attached to the replacement motor mount **450** (or **490**).

Additional steps may include connecting a first bracket member **460** (or **471**) to the motor mount **410** (or **480**) and the replacement motor mount **450** (or **490**), and connecting a second bracket member **460** (or **472**) to the replacement motor mount **450** (or **490**) and the hub **420**. Alternatively, the replacement motor mount **450, 490** may have the brackets **460** (or **471, 472**) formed integrally with the bracket or the brackets may be pre-attached to the motor mount. In still other embodiments, the replacement motor mount **450, 490** may be installed on a new wind turbine as a ready, backup motor mount location. In this way, a technician only needs to move the pitch motor from the old location to the new location. It is envisioned that the replacement motor mounts **450** could be spaced at set intervals around the pitch bearing (e.g., every 10, 20, 30 or 45 degrees). Furthermore, the method **500** may be performed on the wind turbine in-situ, which provides the advantage of not requiring wind turbine rotor or blade removal. This in-situ method **500** provides substantially improved results that were unexpected, because the pitch system can now be repaired without having to remove a rotor blade **22** or the entire rotor **14**. Wind turbines can now be repaired faster and more economically, and put back online more quickly so they may generate sustainable and environmentally friendly electrical power.

The motor mount is not limited to the specific embodiments described herein, but rather, components of the motor mount may be utilized independently and separately from other components described herein. For example, the motor mount and corresponding repair process may also be used with other control systems for controlling bearings (e.g., yaw), and is not limited to practice with only wind turbine blade assemblies as described herein. Rather, the present invention can be implemented and utilized in connection with

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many other pitch or yaw applications. The term "motor" will be understood to include one or more of the motor, drive assembly and/or gearbox.

This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

What is claimed is:

1. A method for repairing a pitch system in a wind turbine, the pitch system including a pitch bearing, a pitch motor and a motor mount for the pitch motor, the method comprising the steps of:

installing a replacement motor mount for the pitch motor; locating the replacement motor mount to displace the pitch motor from the motor mount by a predetermined distance; attaching the pitch motor to the replacement motor mount; and wherein the predetermined distance is chosen to reduce interaction between a geared drive end of the pitch motor and a damaged region of the pitch bearing.

2. The method of claim 1, wherein the predetermined distance spaces the replacement motor mount about 10 degrees to about 25 degrees or more away from the motor mount.

3. The method of claim 1, the installing step further comprising:

connecting a first bracket member to the motor mount and the replacement motor mount.

4. The method of claim 3, the installing step further comprising:

connecting a second bracket member to the replacement motor mount and a hub.

5. The method of claim 1 wherein the installing, locating and attaching steps are all performed on the wind turbine in-situ.

6. The method of claim 5 wherein the installing, locating and attaching steps are all performed on the wind turbine without rotor or blade removal.

7. The method of claim 1, further comprising the step of: removing the pitch motor from the motor mount, wherein the removing step is performed before the attaching step.

8. A method for repairing a pitch system in a wind turbine, the pitch system including a pitch bearing, a pitch motor and a motor mount for the pitch motor, the method comprising the steps of:

installing a replacement motor mount for the pitch motor; locating the replacement motor mount to displace the pitch motor from the motor mount by a predetermined distance; attaching the pitch motor to the replacement motor mount; and

wherein the predetermined distance is chosen to avoid interaction between a geared drive end of the pitch motor and a damaged region of the pitch bearing, and the predetermined distance spaces the replacement motor mount about 10 degrees to about 25 degrees or more away from the motor mount.

9. The method of claim 8, the installing step further comprising:

connecting a first bracket member to the motor mount and the replacement motor mount; and

connecting a second bracket member to the replacement motor mount and a hub. 5

10. The method of claim 9, wherein the installing, locating and attaching steps are all performed on the wind turbine in-situ.

11. The method of claim 10, wherein the installing, locating and attaching steps are all performed on the wind turbine without rotor removal or blade removal. 10

12. The method of claim 11, further comprising the step of: removing the pitch motor from the motor mount, wherein the removing step is performed before the attaching step. 15

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UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 9,140,232 B2
APPLICATION NO. : 13/937244
DATED : September 22, 2015
INVENTOR(S) : Signore et al.

Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the Claims

In Column 6, Line 33, in Claim 2, delete "110" and insert -- 10 --, therefor.

Signed and Sealed this
Twenty-first Day of June, 2016

A handwritten signature in black ink, reading "Michelle K. Lee". The signature is written in a cursive, flowing style.

Michelle K. Lee
Director of the United States Patent and Trademark Office